UNIV. OF
TORONTO
LIBRARY

Digitized by the Internet Archive
in 2016 with funding from
University of Toronto

https://archive.org/details/appliedscienceap09unse

Applied Science

INCORPORATED WITH

TRANSACTIONS OF THE UNIVERSITY OF TORONTO
ENGINEERING SOCIETY

VOL. IX. TORONTO, APRIL, 1915 No. 12

NOTES ON NAVAL ARCHITECTURE AND STEEL SHIPBUILDING.

*J. R. Cockburn, B.A.Sc., A.M. Can. Soc. C.E.

The object of this article is to outline briefly the general principle involved in the design and construction of steel vessels without attempting to go very deeply into any part of the subject.

A great many of the calculations which are made in connection with the design of ships are those dealing with the areas, centres of gravity and moments of inertia of figures bounded by curves, and the volumes and centres of gravity of solids.

There are in general use four different methods of obtaining the areas of plane figures which are bounded on one side by a curve and on the other by a straight line.

1. The first and simplest of these is the trapezoidal rule in which the $\text{area} = h\left(\frac{a}{2} + b + c + d + - \frac{z}{2}\right)$ where $a, b, c, - z$ are the ordinates and h is the common interval between them. See Fig. 1.

It is quite obvious that this method is only approximate.

2. Simpson's First Rule.

$$\text{Area} = \tfrac{1}{3}h\,(a + 4b + 2c + 4d + 2e + 4f + g)$$

A simple proof for this rule is as follows. See Fig. 2.

The area below the curve is practically equal to the area of the trapezoid.

$$\text{Area} = \left(\frac{a+l}{2}\right)\tfrac{2}{3}h + \left(\frac{l+m}{2}\right)\tfrac{2}{3}h + \left(\frac{m+c}{2}\right)\tfrac{2}{3}h.$$

$$= (a + 2l + 2m + c)\,\tfrac{1}{3}h.$$

$$= (a + 4b + c)\,\tfrac{1}{3}h.$$

A second and more exact proof is as follows.

The equation to the curve may be assumed to be $y = a_0 + a_1x + a_2x^2$. See Fig. 3.

$$\text{Area of narrow strip } = ydx.$$

$$\text{whole area } = \int_0^{2h} ydx.$$

---

*Assistant Professor of Descriptive Geometry, University of Toronto.

$$\text{or} \int_0^{2h} (a_0+a_1x+a_2x^2)dx.$$

$$\text{which} = \left[a_0 x + \tfrac{1}{2} a_1 x^2 + \tfrac{1}{3} a_2 x^3 \right]_0^{2h}$$

which has to be evaluated between the limit $x=2h$ and $x=0$. The expression then becomes

$$a_0\,2h+\tfrac{1}{2}\,a_1\,4h^2+\tfrac{1}{3}\,a_2\,8h^3.$$

Now from the equation to the curve when

$$x=0\ :\ y=a_0$$
$$x=h\ .\ y=a_0+a_1\,h+a_2\,h^2$$
$$x=2h\ .\ y=a_0+2a_1h+4a_2h^2$$

But calling the ordinates in the ordinary way $y_1\ y_2,\ y_3$.
when $x=0,\ \ y=y_1,$
$x=h,\ \ y=y_2,$
$x=2h,\ y=y_3,$
therefore $a_0=y_1$
$a_0+a_1h+a_2h^2=y_2$
$a_0+2a_1h+4a_2h^2=y_3.$

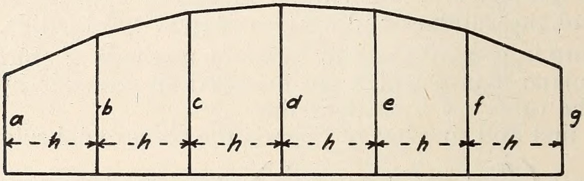


Fig. 1.

$$\therefore a_0=y_1$$
$$a_1=\frac{1}{2h}\ (4y_2-3y_1-y_3)$$
$$a_2=\frac{1}{2h^2}\ (y_3-2y_2+y_1)$$

or substituting above.

$$\text{Area}=y_1\,2h+\frac{4h^2}{2}\cdot\frac{1}{2h}\ (4y_2-3y_1-y_3)+$$
$$\frac{8h^3}{3}\cdot\frac{1}{2h^2}\ (y_3-2y_2+y_1)$$
$$=\tfrac{1}{3}\,h\,(y_1+4y_2+y_3).$$

3. SIMPSON'S SECOND RULE.

Area = $\frac{3}{8}\,h(a+3b+3c+2d+3e+3f+g)$.

Proof assuming that the equation to the curve is

$$y=a_0+a_1\,x+a_2\,x^2+a_3\,x^3$$

Area of narrow strip ydx

$$\text{whole area} = \int_0^{3h} y\,dx$$

$$= \int_{o}^{3h} (a_0 + a_1 x + a_2 x^2 + a_3 x^3) dx$$

which equals $\left[a_0 + \frac{1}{2} a_1 x^2 + \frac{1}{3} a_2 x^3 + \frac{1}{4} a_3 x^4\right]_{o}^{2h}$

which has to be evaluated between the limits $x = 3h$ and $x = 0$.

The expression then becomes

$$a_0 2h + \tfrac{1}{2} a_1 9h^2 + \tfrac{1}{3} a_2 27h^3 + \tfrac{1}{4} 81h^4$$

From the equation to the curve.

When

$$\begin{aligned} x &= 0, & y &= a_0 = y_1 \\ x &= h, & y &= a_0 + a_1 h + a_2 h^2 + a_3 h^3 = y_2 \\ x &= 2h, & y &= a_0 + 2a_1 h + 4a_2 h^2 + 8a_3 h^3 = y_3 \\ x &= 3h, & y &= a_0 + 3a_1 h + 9a_2 h^2 + 27a_3 h^3 = y_4. \end{aligned}$$

Solve the above equations for values of a_0, a_1, a_2 and a_3 and substitute these values in the equation for the area and the result is area $= \frac{3}{8} h(y_1 + 3y_2 + 3y_3 + y_4)$.

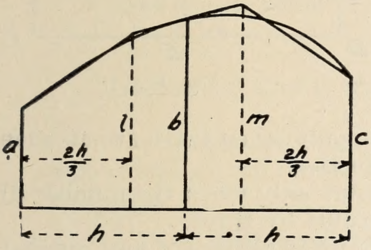


Fig. 2.

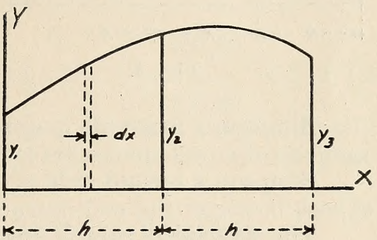


Fig. 3.

4. THE FIVE-EIGHT RULE OR SIMPSON'S THIRD RULE.

$$\text{Area} = \frac{1}{12} h(5y_1 + 8y_2 - y_3)$$

The proof of this rule follows directly from the proof of Simpson's first rule. See Fig. 5.

By Simpson's First Rule

Area of figure $AXBCD = \frac{1}{3} h (AD + 4XE + BC)$.

By the five-eight rule

$$\text{Area } AXED = \frac{1}{12} h \,.\, (5AD + 8XE - BC)$$

$$\text{and area } XBCE = \frac{1}{12} h(5BC + 8XE - AD)$$

Adding these two areas

$$= \frac{1}{12} h (4AD + 16XE - AD)$$

$$= \frac{1}{3} h(AD + 4XE + BC).$$

It should be noted that the result found by the formula is the area between two ordinates only, although three ordinates are required to find it.

The extension of the five-eight rule is as follows:

$$\frac{1}{12}h\left\{\begin{array}{llllll} 5 & 8-1 & & & & \\ & 5 & 8-1 & & & \\ & & 5 & 8-1 & & \\ & & & 5 & 8-1 & \end{array}\right.$$

$$\frac{1}{12}h(5y_1+13y_2+12y_3+12y_4+7y_5-y_6)$$

$$\text{or} = h\left(\frac{5}{12}y_1+\frac{13}{12}y_2+y_3+y_4+\frac{7}{12}y_5-\frac{1}{12}y_6\right)$$

The trapezoidal rule is applicable when there are any number of equidistant ordinates.

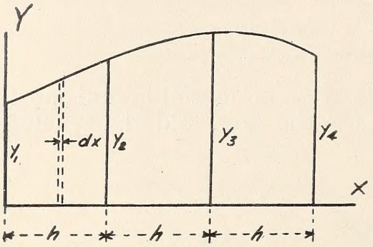


Fig. 4.

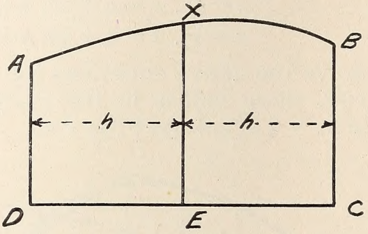


Fig. 5.

Simpson's first rule is applicable only when there are an even number of equal spaces between ordinates.

Simpson's second rule is applicable only when the number of spaces between the ordinates is divisible by three.

The five-eight rule is applicable when there are any number of equidistant ordinates, provided an ordinate beyond the area required be known.

The position of the centre of gravity of a plain figure or solid may be readily found by taking moments about any convenient axis.

The following examples illustrate the method of obtaining the area and position of the centre of gravity of a plane figure bounded on one side by a curve.

1. Solution by Simpson's First Rule.

Distance between ordinates = 2′ 0″.

No.	Length of Ordinate	Simp. Mult.	Functions of Ordinate	Levers	Products
1	1.45	1	1.45	0	0.0
2	2.65	4	10.60	1	10.60
3	4.35	2	8.70	2	17.40
4	6.45	4	25.80	3	77.40
5	8.50	2	17.00	4	68.00
6	10.40	4	41.60	5	208.00
7	11.85	1	11.85	6	71.10
			117.00		452.50

$$\text{Area} = \frac{1}{3}(117\text{x}2) = 78 \text{ sq. ft.}$$

$$\text{Distance of C of G from section No. 1} = \frac{452.50}{117} \times 2 = 7.72 \text{ ft.}$$

2. Solution by Simpson's Second Rule.

No.	Lenth of Ord.	Simp. Mult.	Functions of Ordinate	Levers	Products
1	1.45	1	1.45	0	0.0
2	2.65	3	7.95	1	7.95
3	4.35	3	13.05	2	26.10
4	6.45	2	12.90	3	38.70
5	8.50	3	25.50	4	102.00
6	10.40	3	31.20	5	156.00
7	11.85	1	11.85	6	71.10
			103.90		401.80

$$\text{Area} = \frac{3}{8}(103.90\text{x}2) = 77.925 \text{ sq. ft.}$$

$$\text{Distance of C of G from section No. 1} = \frac{401.80}{103.90} \times 2 = 7.71 \text{ ft.}$$

The results obtained by the two methods are practically the same, and either result is sufficiently accurate for all practical purposes.

Displacement and Centre of Buoyancy.

The displacement of a vessel may be expressed either in units of weight or in units of volume, the weight of the vessel being equal to the weight of the water which it displaces when floating.

The centre of buoyancy of a vessel is always in the same vertical line as its centre of gravity, and may be defined as the centre of gravity of the volume of water displaced.

In order to find the volume of the underwater portion of a vessel, the body is intersected by a series of equidistant planes. The area of each section is then found by one of the rules already explained, or by means of the planimeter.

The areas thus found are treated as the ordinates of a new curve, the area of which will represent the required volume. The position of the centre of gravity may be found as previously explained.

As the hull of a vesel is symmetrical about the fore and aft central plane, it is usual to make cauculations for one side only.

The equidistant planes, which are taken to intersect the hull, may be parallel to the load water line plane, or they may be perpendicular to the load water line and fore and aft central planes.

The first series of planes will give the vertical position of the centre of buoyancy, and the second series its longitudinal position.

In calculations of displacement, three coefficients are often used. They are as follows:—

1. The Block Coefficient, or the ratio between the displacement and the product of the length between perpendiculars, the moulded beam and the moulded draft $= \dfrac{\text{displacement}}{L \times B \times D}$

2. The Prismatic Coefficient, or the ratio between the displacement and the product of the length between perpendiculars and the midship section below the load water line.

3. The Midship Section Coefficient, or the ratio between the midship section and the product of the moulded beam and draft amidships.

Tonnage.

The term ''tonnage'' must not be confused with the displacement in tons, as there is no relation between tonnage and displacement.

In the early days of British shipping a great deal of the trade consisted in carrying wine from France to Great Britain. The wine was carried in large casks called tuns, which were all of nearly the same size, so a handy way of reckoning the size of a ship was to state how many tuns of wine she could carry. The tun of one hundred cubic feet was finally adopted as the British unit for measuring a vessel's capacity.

The word tunnage has since been corupted into tonnage.

If the tonnage of a vessel be given as 10,000, it simply means that the internal capacity of the ship is 10,000 × 100 cubic feet.

Calculation of Weights.

It is possible to calculate from the detailed drawing the weights of the principal portions of a ship, such as shell plating, inner bottom plating, framing, steel and wood decks, platforms, beams, bulkheads, etc. There are, however, a great many parts the weight of which cannot be readily calculated, and it is usual to estimate their weights by comparison with those of existing ships. Such parts are stems, and stern frames, shaft brackets, engine and boiler foundations, rudders, paint, cement, fittings, etc.

As it is a very laborious calculation to determine the weight of a large ship in detail, it is common practice, especially in preliminary work, to estimate the weight by comparison with existing ships of nearly the same size and type, the weights of such ships being known. If two ships be of the same type and proportions, their weights must be to one another as the products of their lengths, breadths and depths.

Let $L =$ Length between perpendiculars in feet.
Let $B =$ Breadth moulded in feet.
Let $D =$ Depth moulded in feet.
Let $N = \dfrac{L \times B \times D}{100}$

Then the weight of hull = N × Ch.
the weight of steel = N × Cs.
the weight of wood and fittings = N × Cw.

The following table taken from Kemp's Engineer's Year Book (1913) gives the average values of the coefficients, Ch, Ss and Cw:—

Type of Vessel.	Cs.	Cw.	Ch.
Torpedo boat destroyer	.25	.09	.34
Cruiser	.30	.11	.41
Battleship	.33	.14	.47
River paddle steamer	.20	.10	.30
Channel steamer	.25	.13	.38
Coasting steamer	.32	.20	.52
Cargo tramp	.35	.12	.47
Intermediate liner	.42	.17	.59
Fast mail liner	.39	.14	.53

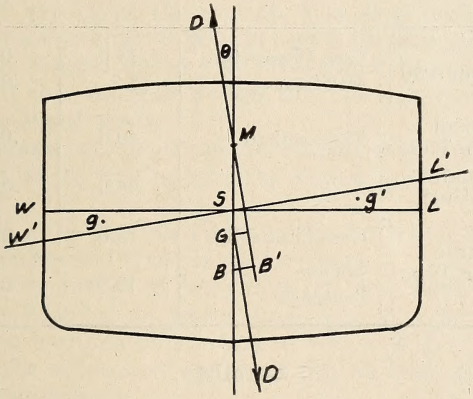


Fig. 6.

In calculating the weights of machinery the methods employed are similar to those used to obtain the weight of the hull. In preliminary estimates the weights may be taken as being proportional to power.

In addition to the weights of the hull and machinery of a vessel, it is necessary to calculate the deadweight which the ship is to carry. The deadweight consists of such things as spare gear, crews and effects, passengers, baggage, coal, and everything else not included in the estimate of the hull and machinery.

The following table, which is taken from Kemp's Engineer's

Hand Book (1913), gives coefficients for the weights of various types of machinery:—

Type of Machinery	Type of Boiler	Type of Ship	H.P per Ton	Tons of Engine per H.P.	Tons of Boiler per H.P.
RECIPROCATING ENGINES	Cylindrical	Cross Channel Str. Cruiser Battleship	9	.041	.070
	Cylindrical	Cargo Str. Forced D.	4.5	.113	.109
		Cargo Str. Nat. D.	4.2	.125	.113
		Mail Steamer	6 0	.082	.085
	Small Water Tube	Torpedo Craft	40.0	.0127	.0123
	Large Water Tube	Cross Channel Str.	11.6	.0410	.0373
		Cruiser Battleship	12.8	.0410	.0370
TURBINES	Cylindrical	Cross Channel Str.	13.0	.022	.055
		Mail Steamer	8.5	.040	.078
	Small Water Tube	Torpedo Craft	40.0	.0127	.0123
	Small Oil Fuel	" "	48.0	.01	.0104
	Large Water Tube	Cross Channel Str.	15.0	.0220	.0450
		Cruisers Battleships	13.30	.038	.037

Stability.

The Statical Stability of a vessel is the property she has of retaining an upright position, and is of the utmost importance in regard to safety.

The statical stability of a vessel remains fairly constant for all angles of heel up to between 10° and 15°, and the stability within such limits is known as the initial statical stability.

The stability of a vessel may be compared to that of a sphere in which the centre of gravity does not coincide with the centre of the sphere. When such a sphere is placed upon a horizontal plain surface it will take a position such that its centre of gravity is directly below its geometric centre, and if forced from this position by an external force, it will immediately return to it when the outside force is removed.

In the case of a vessel floating in still water, the point about which it virtually rotates when rolling from side to side is known as the transverse metacentre. In order for the vessel to be in a state of stable equilibrium, this metacentre must be above the centre of gravity.

The inclinations of a vessel in a longitudinal or fore and aft direction are of importance in determining the trim under varying conditions of loading. Such inclinations take place about a point known as the longitudinal metacentre. The principles involved in determining the positions of the two metacentres are essentially the same. It is therefore sufficient to illustrate the method of obtaining either one of these.

The distance that the metacentre is above the centre of buoyancy is usually expressed as BM, and its value may be found from the following equation:—

$$BM = \frac{I}{V}$$

where I = Moment of inertia of the figure inclosed by the load water line.
V = Volume of displacement.

The proof of the formula is as follows:—

Let Fig. 6 represent the section of a ship inclined from the upright by some external force through a small angle θ.

The wedge-shaped volume WSW′, which has come out of the water, is called the emerged wedge, and the other wedge, LSL′, is called the immersed wedge.

As the volume of displacement of the ship is the same after being inclined as it was before the volumes of the two wedges must be equal.

Let g and g^1 be the positions of the centre of gravity of the emerged and immersed wedges respectively.

Let B be the centre of buoyancy of the vessel in an upright position when floating at water line WL, and B^1 the centre of buoyancy when inclined and flating at water W^1L^1.

Let v be the volume of either of the wedges, and V the total volume of displacement.

As the change of position of the centre of gravity of the small volume v from g to g^1 is equivalent to changing the centre of gravity of the whole volume V from B to B^1, we may write $B\,B^1 \times V = g\,g^1 \times v$.

$$\text{or } BB' = \frac{v \times gg'}{V}$$

and for a very small angle of inclination

$$\frac{B'B}{BM} = \sin\theta \text{ or } B'B = BM \sin\theta.$$

If y be the half breadth of the water line we can write

$$WW' = LL' = y \sin\theta$$

and the area of the triangle WSW' or

$$LSL' = \tfrac{1}{2}y \times y \sin\theta = \tfrac{1}{2}y^2 \sin\theta.$$

As θ is very small the distance $gg' = \tfrac{4}{3}y$. Therefore the moment caused by the transference of the displacement from one side to the other

$$= \tfrac{1}{2}y^2 \sin\theta \times \tfrac{4}{3}y = \tfrac{2}{3}y^3 \sin\theta.$$

And for a very small length dx of the water line the moment is

$$\tfrac{2}{3}y^3 \sin\theta dx.$$

Making a summation for the whole length of the ship

$$\text{Moment } V \times gg' = \int \tfrac{2}{3}y^3 \sin\theta dx.$$

$$= \tfrac{2}{3}\sin\theta \int y^3\,dx.$$

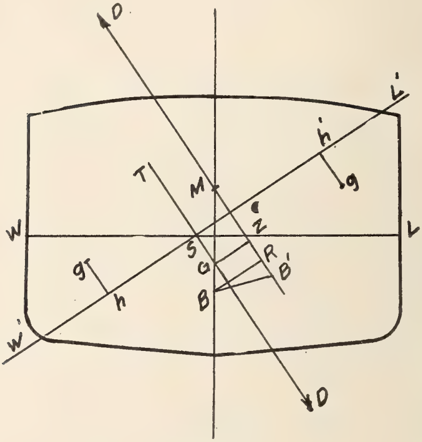


Fig. 7.

$$\therefore BB' = BM \sin\theta = \frac{V \times gg'}{V} = \frac{\tfrac{2}{3}\sin\theta \int y^3 dx}{V}$$

$$\text{or } BM = \frac{\tfrac{2}{3}\int y^3\,dx}{V}$$

But $\tfrac{2}{3}\int y^3 dx$ is the expression for the moment of inertia of the load water line about its longitudinal axis.

To determine the righting moment of a vessel.

Let G be the position of the centre of gravity and D the weight of the vessel. The righting moment $= D \times GM \sin\theta$. The moment of inertia of the load water line may be calculated by applying one of Simpson's rules, the cubes of the half breadths being used instead of the half breadths as used in computing the area.

The method is illustrated in the following table:—

No.	Half Breadths	Cubes of H.B.	Simp. Mult.	Products
1			1	
2			4	
3			2	
4			4	
5			2	
6			4	
7			2	
8			4	
9			1	
				Sum of Prod. = P.

$P \times \frac{1}{3}$ common interval = area of curve of ordinates cubed, $\frac{8}{12}$ of this, or $\frac{2}{3}\, P \times \frac{1}{3}\, CI$ = moment of inertia of the load water line.

Statical Stability at large Angles of Heel.

Let Fig. 7 represent the cross section of a vessel inclined at a large angle θ.

The righting moment of the ship is $D \times GZ$

$$GZ = BR - BP$$
$$= BR - BG \sin \theta.$$

The moment of statical stability

$$= D(BR - BG \sin \theta)$$

$$\text{But } BR = \frac{V \times hh'}{V}$$

∴ Moment of statistical stability

$$= D\left(\frac{V \times hh'}{V} - BG \sin \theta\right).$$

This is known as Atwood's formula.

Dynamical Stability.

When a vessel is inclined through an angle by an external force the work done on the ship is equal to the weight of the ship multiplied by the vertical separation of its centre of gravity and centre of buoyancy The amount of this work is what is called the dynamical stability.

In Fig. 7 the vertical distance between the centres of gravity and buoyancy when the ship is inclined through an angle θ is $B'Z$

The original vertical distance is BG

$\therefore$ the vertical separation is

$$B'Z - BG$$

$\therefore$ the dynamical stability $= D(B'Z - BG)$.

Now $B'Z = B'R + RZ = B'R + BG \cos\theta$.

$$V(gh + g'h') = V \times B'R$$

$$\text{or } B'R = \frac{V(gh + g'h')}{V}$$

Substituting in the above value of $B'Z$, we obtain

$$B'Z = \frac{V(gh + g'h')}{V} + BG \cos\theta$$

$\therefore$ the dynamical stability

$$= D\left[\frac{V(gh + g'h')}{V} - BG(1 - \cos\theta)\right]$$

This is known as Mosley's formula.

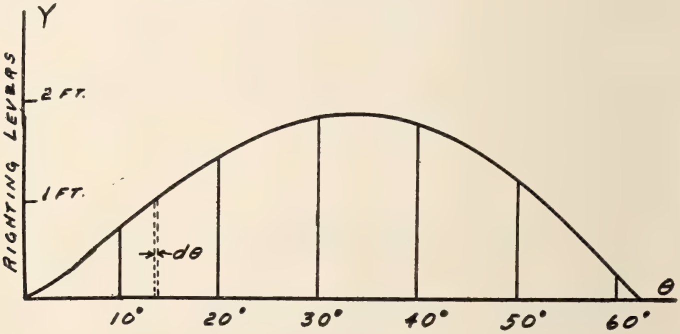


Fig. 8.

In Fig. 8 we have the curve of statical stability of a battleship plotted for various angles of heel. The ordinates represent the righting levers on a certain scale, and the righting moments on another scale, which is equal to the scale of righting levers multiplied by the weight of the vessel.

It is interesting to note that the area of the curve of statical stability up to any given point represents the dynamical stability up to the same point. This can be readily proved as follows:—

The work done in inclining the vessel through a small angle

$d\theta$ is equal to the product of the moment and the angle through which the moment acts, the angle being expressed in radians.

$$= yd\theta.$$

The total work done in inclining the vessel from the upright to the angle in question, viz. θ . $= \int yd\theta$ but $\int yd\theta$ equals the area of the curve.

As the righting moment of a vessel depends upon the relation of the metacentre to the centre of gravity, it is always necessary to calculate the position of the centre of gravity of the ship as a whole before any knowledge of the stability can be gained.

The following are average values of the height of transverse metacentres above the centres of gravity for different types of vessels:—

For a Battleship	3′—6″
‘‘ Cruiser	2′—6″
‘‘ Large cargo vessel	2′—0″
‘‘ Paddle steamer	2′—0″
‘‘ Cross Channel steamer	1′—6″
‘‘ Transatlantic mail steamer	1′—0″

The reason for such a great metacentric height in battleships is in order to give sufficient stability for gunfire.

The more nearly the metacentre approaches to the centre of gravity, the more slowly will the vessel roll, and for that reason a transatlantic mail steamer is given a metacentric height as small as is permissible with safety.

Structural Requirements of Ships.

The three principal classes of stresses experienced by ships are as follows:—

(1 Those caused by longitudinal bending and shearing forces.

(2) Transverse strains.

(3) Strains due to the propulsion of the vessel.

In addition to the above there are a great number of local strains due to a variety of causes, such as heavy local weights, attachment of rigging, etc.

The longitudinal bending and shearing stresses are caused by the uneven distribution of weight and buoyancy, this condition being greatly aggravated by the action of waves. When a vessel is supported upon the crest of a wave of her own length the stresses tending to produce hogging are at a maximum, and when the vessel rests across the trough of a wave upon two crests the stresses tending to produce sagging are at a maximum.

Fig. 9 shows graphically the distribution of weights and buoyancy for a ship when subjected to hogging stresses.

The curve B shows the distribution of the buoyancy or displacement.

The curve W shows the distribution of the weight of the vessel.

The curve L shows the difference between the weight and buoyancy at the various sections. It is called the curve of loads, and from it the curves of shearing forces and bending moments may be calculated by the ordinary methods of statics.

Fig. 10 shows the corresponding case for the ship when subjected to sagging strains.

In order to determine the maximum stress at any section of the ship, it is necessary to calculate the moment of inertia of the section and the position of its neutral axis. The formula $\frac{p}{y} = \frac{M}{I}$ may then be employed.

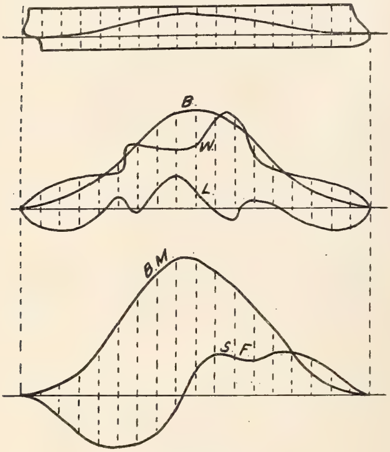


Fig. 9.

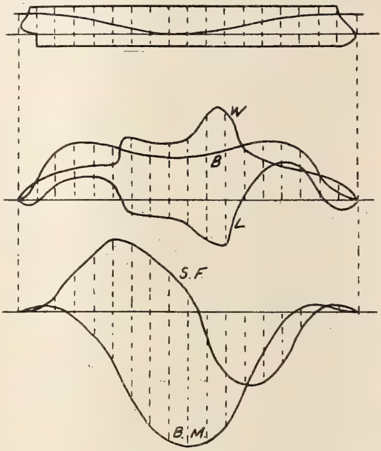


Fig. 10.

In designing the cross-section of a ship the deck houses and superstructures which are liable to stress must be embodied in the design and made sufficiently heavy, or serious injury to them will result.

The maximum bending moment in foot tons for ordinary ships may be assumed to be between $\frac{1}{20}$ and $\frac{1}{30}$ of the product of the length in feet and the displacement in tons, and will usually occur in the neighborhood of the midship section.

The shearing force is usually zero at the midship section, and a maximum midway between the midship section and the ends.

The stresses caused by the action of waves are greatly influenced by the inertia of the water, and by the motion of the vessel. According to the trochoidal theory of waves, the particles of water move with a circular motion, and this motion materially modifies the supporting power of the waves.

It might be worthy of note that the maximum permissible bending stresses in a ship 500 feet long will cause the vessel to bend as much as 6 inches, and it has been found in certain cases that a change in temperature of 7° will bend the ship over 1 inch.

The longitudinal stresses are resisted principally by the shell plating and decks.

The transverse stresses are caused mostly by racking strains due to rolling and the action of waves. They are very difficult to determine, but are much smaller in amount than the longitudinal stresses. The transverse framing and blukheads are the principal members which resist transverse strains.

Resistance and Propulsion of Ships.

The resitance to be overcome by a ship passing through the water may be divided into three parts:—

1. Skin resistance, which is due to the friction of the water on the sides of the vessel.
2. Eddy-making resistance.
3. Wave-making resistance.

The first of these depends upon the length, area and nature of the surface, and upon the density of the water. It varies as the nth. power of the speed where n varies from 1.83 to 2.16.

The eddy-making resistance varies approximately as the square of the speed, but it will vary in amount according to the shape of the ship. A ship with full stern and thick stern post and rudder will have a greater eddy-making resistance than one with a fine stern and thin stern post and rudder.

The effective horse power (E.H.P.) required to overcome the frictional and eddy making resistance may be calculated from the following formula

$$\text{E.H.P.} = \frac{1}{326} f S V^{2.83}.$$

Where V is the speed in knots.
S the area of wetted surface in sq. ft.
f a coefficient, varying from 0.009 for a length of 500 ft. to 0.01 for a length of 40 ft.

The wave-making resistance of a vessel depends upon a great many variable factors, such as the size and proportions of the vessel, the speed at which the vessel is travelling, etc.

The most accurate method of estimating the wave-making resistance of a vessel is by using the results of experiments with models, or with actual ships, and comparing them by means of Froud's law, which is as follows:—

If two vessels of exactly similar form, but of different sizes, are run at speeds proportional to the square roots of their lengths, their wave-making resistances will be proportional to the products of their displacements and speeds.

An approximate formula for the effective horse power required to overcome wave making resistance is

$$\text{E.H.P.} = \frac{1}{326}\ b\ \frac{(W)^{\frac{2}{3}}}{L}\ V^5$$

where W is the displacement in tons.
L is the length in feet.
V the speed in knots.

As the coefficient b varies for different speeds in the same ship the formula is unreliable.

The ratio of the effective horse power to the indicated horse power may be expressed as follows $\frac{\text{EHP}}{\text{IHP}} = .63$ to .45.

The Admiralty coefficient of propulsion which is expressed as follows $C = \frac{W^{\frac{2}{3}} V^3}{P}$ is used to obtain the total indicated horse power required to propel a vessel at a given speed.

The total power required may be found by substituting the proper value for the coefficient in the formula $P = \frac{W^{\frac{2}{3}} V^3}{C}$.

The following table gives possible values for the admiralty coefficient c:—

Length.	Coefficient.	L.	c.	L.	c.
100	137	350	289	650	315
150	188	400	297	700	217
200	277	450	303	750	319
250	255	500	307	800	321
300	275	550	310	850	323
		600	312		

The values given in the above table apply to reciprocating machinery. For turbine propulsion the values of c are about 16% less than those given in the table.

A rough approximation to the relation between Speed and Indicated Horse Power may be expressed as follows

$$\text{I.H.P.} = \frac{S}{100} \times \left(\frac{V}{10}\right)^3 f$$

where S = wetted surface in square feet.
V = speed in knots.
f = a coefficient which varies from 5 to 7 for ordinary vessels.

The Design and Construction of a Steel Vessel.

Before the construction of a vessel is commenced, the general drawings, as well as certain detail drawings should be prepared.

The most important drawing, and in fact the drawing upon which all details of the hull are founded, is called the sheer draft, or lines of the vessel. This drawing consists of the representation of the following lines:—

1. The water lines or intersections of the hull by planes parallel to the load water line plane.
2. The cross-sections or intersections of the hull by transverse vertical planes.
3. The buttocks and bow lines or intesections of the surface of the hull by longitudinal vertical planes.
4. The diagonals or the intersection of the surface of the hull by longitudinal planes inclined to the horizontal.

These lines are represented by their orthographic projections on the three following planes:—

1. A horizontal plane.
2. A vertical plane parallel to the longitudinal axis of the vessel.
3. A second vertical plane at right angles to the others.

In drawing the "lines" for a ship the following conditions must be complied with:—

(a) The displacement as calculated from the lines must equal the total weight of the vessel.

(b) The position of the centre of buoyancy as calculated must be in the same vertical line as the centre of gravity of the ship.

(c) The transverse metacentre must be a sufficient distance above the centre of gravity to insure safety without being so high as to cause violent rolling when subjected to the action of waves.

(d) The lines must be "fair"—that is, they must be so that the surface of the vessel will have no irregular hills or hollows.

The process of correcting the "lines" to conform to the requirements is known as "fairing" the lines. It is a fairly tedious process, and is carried out by the method of trial and error.

When the lines of a vessel are faired on a small scale drawing they must be copied full size upon the mould loft floor and carefully "faired."

The information necessary for laying off the lines on the loft floor is furnished to the loftsmen in the form of a table called the table of bodies. This table contains all necessary dimensions arranged in the most convenient form for reference.

When the lines are faired on the loft floor the next thing to do is to make what is known as a scrieve board. This consists of a floor or platform made of fairly good tongue and grooved flooring. This is in fact a large drafting board, on which the cross-sections of the vessel are drawn full size. All the lines on a scrieve board are cut or scrieved well into the board, so as to render them sufficiently permanent.

The following information must be placed on the scrieve board: The moulded shape (shape inside plating) of every frame, the positions of all shell plating edges, longitudinal stringers, decks, and everything that comes in contact with the framing of the vessel.

The scrieve board is placed in a convenient position for the furnace and platform men to refer to when turning (bending and bevelling) the frames.

Turning the Frames.

The main transverse frames of a vessel are usually of angle, bulb angle or channel section, and must be of very mild open hearth steel. Ordinary structural steel is difficult to work, and the frames are often injured while being adjusted to shape after cooling when made of hard material.

The frames are first brought to a white heat in a specially constructed furnace and then bent around a thin strip of metal which has been previously brought to the right shape and fastened by suitable dogs to the iron-bending slabs. The bevelling is done at the same time, the bevels being lifted from the scrieve board.

Lifting the bevels is a very simple matter, because the bevel of a frame at any given point is directly proportional to the distance between its projection on the scrieve board and the corresponding projection of the next frame to it. For example, if the frames in the ship be spaced 24 inches apart and the distance from a point on a frame to the nearest point on another frame, which is one space nearer the midship section, be 2 inches, the bevel of the frame at that point must be 2 in 24, or 1 in 12.

As soon as the frames, keel, stem and stern frames are completed in the shop the framing of the vessel may be set up.

A great deal of the plating of the vessel, such as bulkheads, decks and steel deck houses, may be laid out from the mould loft and scrieve board, but the only satisfactory method of plating the outside of the hull is by the templet system. The plating lines are all marked on the frames from the scrieve board, and these lines are the guides for the shell templets.

The templets for laying of the shell plates are made of thin soft lumber in strips ranging in width from 4 inches upward, and of about ¼ inch in thickness. A skeleton templet is built up in such a way that a strip of wood will cover each endge of the plate and also every frame in contact with the plate. This templet is placed in contact with the frames and the holes are marked by means of white lead. The templet is then transferred to the proper plate and the holes marked off.

In ordering the shell plating for a vessel it is usual to make a block model of one-half the ship, and draw the plating right on the model. The plates may then be traced on paper and measured.

The plating of a vessel may be arranged in three different ways.

The first and simplest method is to have all seams, both transverse and longitudinal, lap joints. This is the usual practice in the case of tugs and freighters.

The second method is to have the longitudinal seams lap and the transverse seams butt joints. This is the usual practice in the case of passenger steamers and yachts.

The third method is to have all seams butt joints. This method makes the outside surface of the vessel smooth and all seams invisible. It is, however very rarely restorted to on account of the expense involved in planing all edges of plates to an exact lines and the additional riveting required.

The plating of a vessel is rendered watertight by caulking the seams between the plates, from the outside. It is not usual to caulk the butt straps or the inside edges of the plates.

When the hull of a vessel is completey plated, caulked and painted and all underwater portions of the machinery and fittings are in place the vessel is ready for launching.

INTERNATIONAL ENGINEERING CONGRESS, 1915.

September 20-25, San Francisco, Cal., U.S.A.

Volume IV. of the transactions of the Congress will comprise an important series of papers on the general subject of Railways and Railway Engineering. This field will be treated under seven principal topics covering relation of railways to social development; present status of railways; economic factors governing building of new lines; location; physical characteristics of road, including track and roadbed; bridges; tunnels; terminals; construction methods; signals; road equipment, including motive power other than electric; rolling stock in general; floating equipment; electric motive power in general.

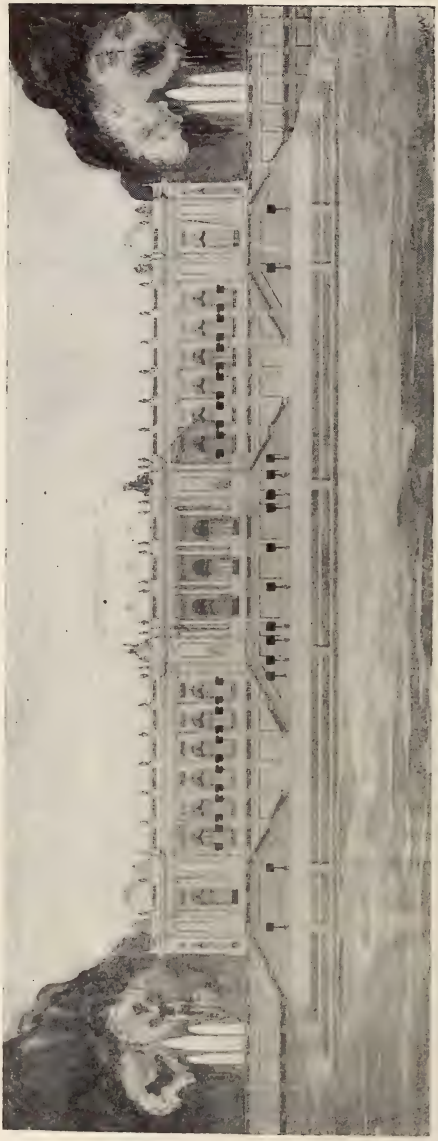
Approximately 27 papers are expected for this volume, prepared by authors representing 9 different countries. The list of authors includes many of the most eminent names in this field of engineering work throughout the world.

The volume as a whole will be illustrated with charts, diagrams and half-tones, together with discussions contributed by leading American and foreign engineers, and will form a most valuable acquisition to the library of all engineers and others who may be interested in these phases of engineering work.

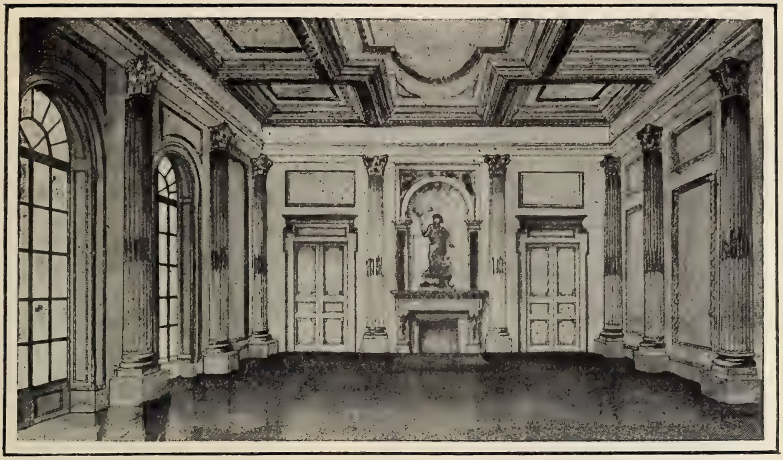
The transactions of the Congress as a whole will include nine or ten other volumes, covering the various fields of engineering work.

Membership in the Congress with the privilege of purchasing any or all of the volumes of the proceedings is open to all interested in engineering work. Those interested may secure fuller information from the Secretary, Mr. W. A. Cattell, 417 Foxcroft Building, San Francisco, Cal.

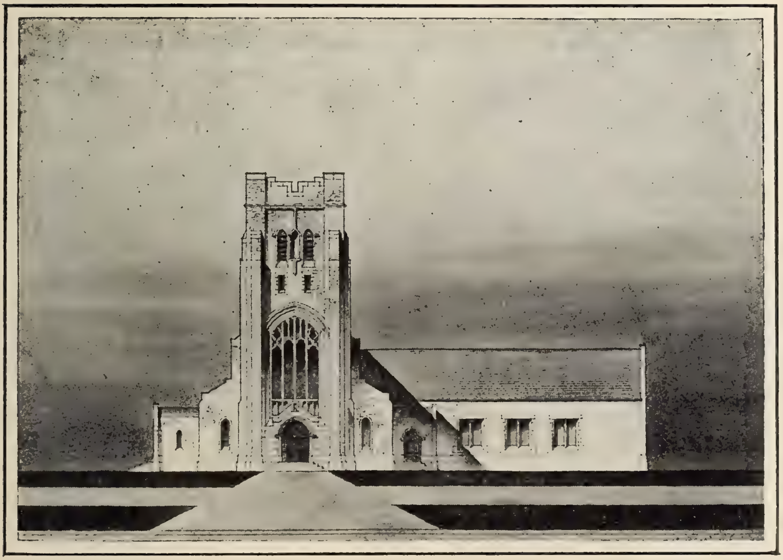
H. S. Clark, B.A.Sc., '10, who was previously engaged on the Welland Ship Canal construction, has been on military duty with the frontier guard at Niagara Falls, Ont., since August until recently, when he received a lieutenancy in the 36th Battalion of the Third Contingent. He is now at regimental headquarters, Hamilton, Ont.



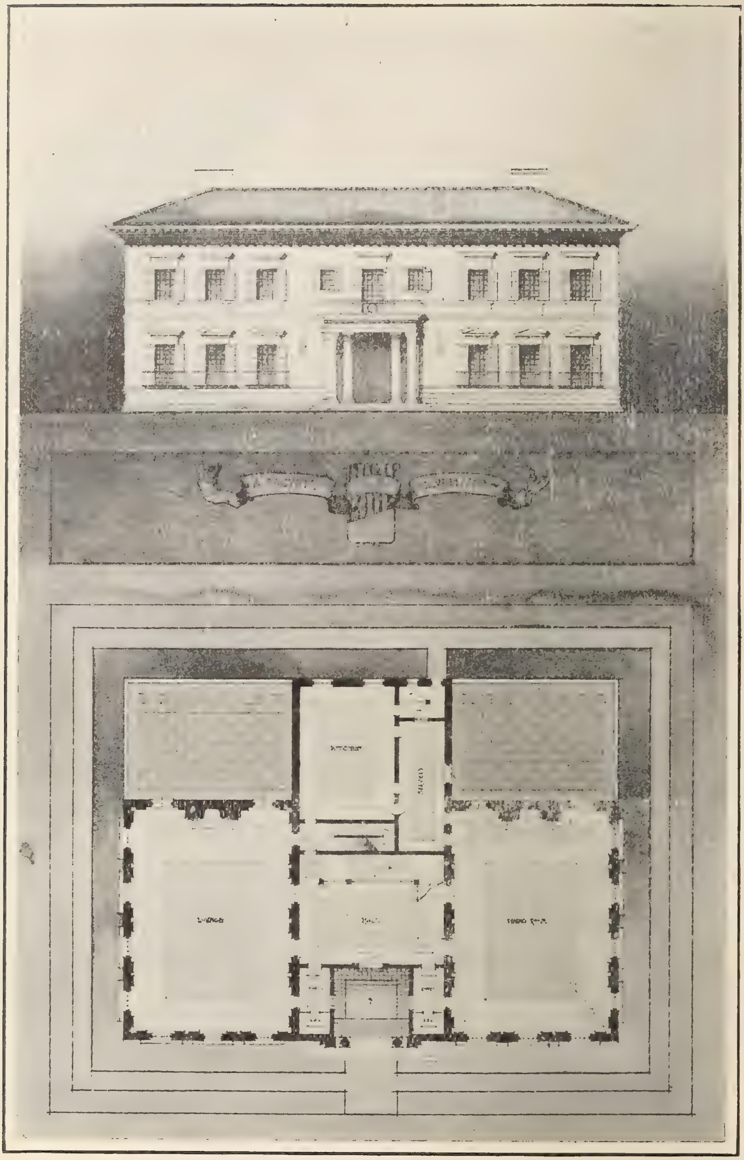
A CASINO.—K. C. Burness, 4th year.



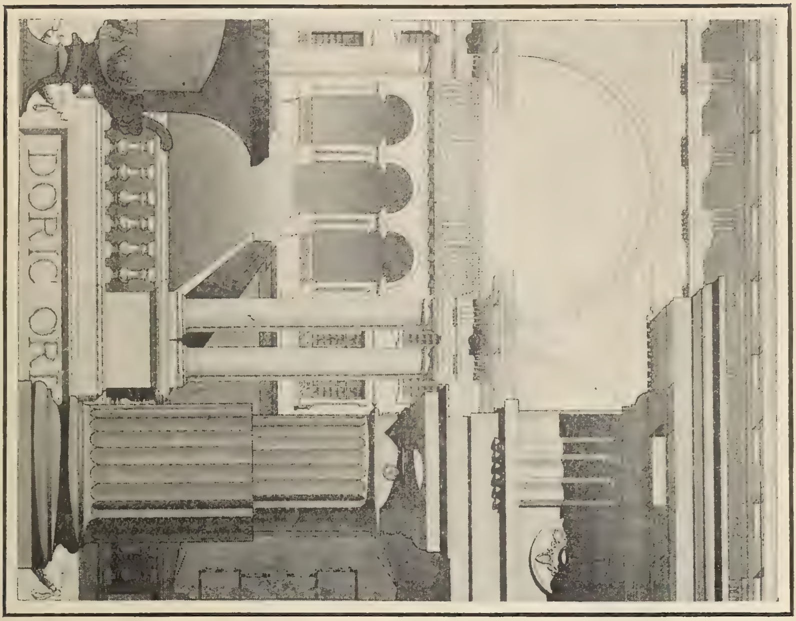
A STATE DINING ROOM.—W. S. Kidd, 3rd year.



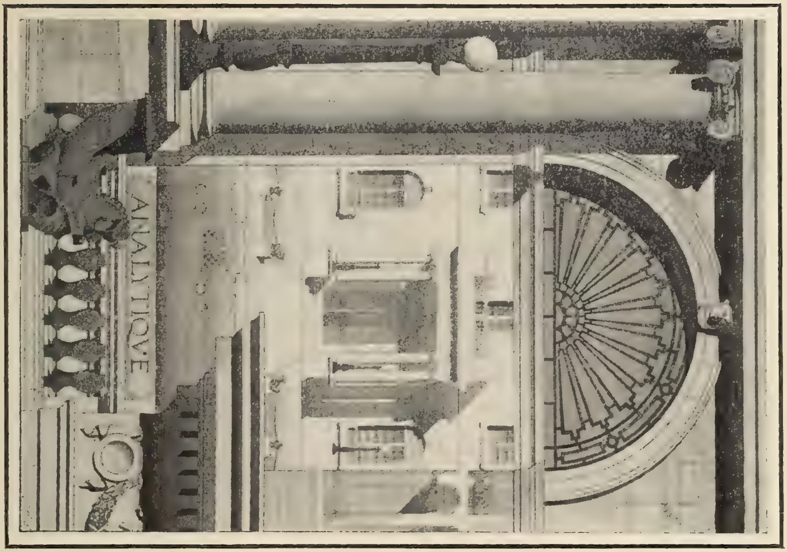
A VILLAGE CHURCH.—J. L. Skinner, 3rd year.



A FACULTY CLUB.—C. C. Thompson, 2nd year.



DORIC ORDER.—G. R. Gounlock, 1st year.



ENTRANCE TO A CITY RESIDENCE.—O. H. McAvoy, 1st year.

ARCHITECTURAL CLUB EXHIBIT.

The Architectural Club of the University of Toronto Engineering Society, under the leadership of Chairman T. S. Graham, '15, and Vice-Chraiman K. C. Burness, '15, has, during the past year, enjoyed an unusually active and successful term. The third annual exhibit, which was held in Convocation Hall on March 29, 30 and 31, was the most complete and encouraging exhibit of this nature which the club has yet conducted. In addition to the more elaborate designs, it included a good display of freehand drawings and clay modelling.

A distinctive feature was the Dominion Government Power House Competition, for which first, second and third prizes of $25.00, $15.00 and $10.00 respectively, were awarded by the Water Power Branch, Department of Interior, Ottawa. First prize was awarded to H. R. Watson, '17, second prize to G. R. Edwards, '15, and third prize to H. J. Burden, '15.

About three thousand visitors, including a large representation of the profession from down town, attended the exhibit, and considerable surprise and pleasure was voiced at the high standard of the work, especially that of the junior years.

A few cuts appear in this number of "Applied Science," illustrating the work of the different years. Additional illustrations will be shown in future numbers, as we believe that our readers will be interested in the work which is being carried on by this section of the Engineering Society.

*INTERESTING ITEMS IN THE GROWTH OF THE STUDY OF APPLIED SCIENCE.

In seeking for the origin of the Faculty of Applied Science we must go back to Prince Albert, Consort of Queen Victoria.

That wise and good prince, deeply convinced of the benefits to be derived from the application of science to the problems of industry, exerted himself to arouse in the people of Great Britain a sense of the value of Applied Science. The first fruit of his labors was the great Exhibition of 1851, planned by him to demonstrate the advantage of science to the arts and the mutual benefits of commerce among the nations.

The Exhibition was followed by a great awakening of interest in Applied Science, which led in England to the manifold activities which are associated with the words "South Kensington." Prince Albert was not only an enlightened statesman; he was also an affectionate and careful father, and he spared no pains to fit

---

*Extracts from remarks of Dr. Ellis, at Engineering Society Dinner, Feb. 1915.

his children for their exalted destiny by giving them what he considered to be the best education in his power. Educated at Bonn, he had a high opinion of the value of chemistry, and a great respect for Liebig, and he secured a pupil of Liebig, Dr. Lyon Playfair, afterwards Baron Playfair of St. Andrews, the only chemist so far as I know who ever became a Cabinet Minister, as tutor for his son, his late Majesty Edward VII. Lord Playfair told me that on one occasion he took his royal pupil to visit a certain foundry. The foreman, who was showing them over the works, plunged his hand into a crucible of molten metal and withdrew it unscathed. The Prince was greatly interested in the experiment, and asked to repeat it on his own person. On Mr. Playfair enquiring of the foreman if it would be quite safe, the foreman asked leave to feel the Prince's hand, and having done so, replied that it would be quite safe, as the royal hand was just right, neither too damp nor too dry. On receiving permission, the Prince, without hesitation, performed the experiment with perfect success.

Prince Albert's eldest daughter was the Crown Princess of Prussia, the mother of the present Kaiser. She inherited a large measure of her father's ability and character, and she did her best to instil into the mind of her son the liberal principles of her father. Unfortunately, there were other influences brought to bear upon him which proved too strong for her. When he plunged his hand into the seething crucible of world politics, it was not the cool, calm hand of faith and reason, but the mailed fist of passion and the lust of power, and the explosion caused by that experiment has set the world ablaze.

The interest aroused in England in 1851 took about twenty years to reach Canada. In 1871 Mr. John Sandfield Macdonald, then Premier of Ontario, proposed the establishment of a College of Technology. The Government bought the Mechanics' Institute building at the corner of Church and Adelaide Streets, and fitted it up for this purpose. There were at that time in the Parliament of Ontario a number of brilliant University men ,such as Edward Blake, afterwards Chancellor of the University; Thomas Moss, afterwards Chief Justice and Vice-Chancellor of the University, and Adam Crooks, afterwards Minister of Education. These men viewed the proposed College of Technology with grave misgiving as a step in the wrong direction, and advocated, both on the score of economy and efficiency, the teaching of Applied Science by the Provincial University, strengthened where necessary by additional chairs and additional equipment maintained by the public funds.

When Sandfield Macdonald's government was defeated and Alexander Mackenzie came into power, Adam Crooks became Minister of Education, and a scheme was prepared for carrying out technical education in accordance with the views of himself and his advisors.

The name "College of Technology" was changed to "School of Practical Science," and a building that is now known as the Engineering Building was erected on University property, where laboratories were equipped for the teaching of science open to students of the University and of the School of Practical Science alike.

Under Sir George Ross as Minister of Education in 1889 the University Federation Act came into force, a University teaching staff was appointed and University labortories were equipped.

The School of Practical Science was separated and became an affiliated college, with Dr. John Galbraith as Principal.

Finally the University Act of 1906 formally united the School of Practical Science with the University, as its Faculty of Applied Science and Engineering, a position which it has virtually held since 1878.

EXTRACTS FROM REMARKS OF REV. DAVID M. STEELE AT A DINNER OF THE ALUMNI OF THE RENSSELAER POLYTECHNIC INSTITUTE.

Four things seem to me to mark students and faculty alike of an institution such as this. These qualities go far to mark the men in your profession even after they are out of school. All four of them are illustrated tonight in multiples of one hundred. I note here the characteristics of industry, accuracy, modesty and courage.

Industry: Of all the hard-working members of the student body of this country, I am willing to grant that your students are the most nearly overworked; while, of all the men who keep on being students after they are out of college, you men probably study the hardest. One reason for this is that your very calling requires you to think clearly—and that never was easy.

Accuracy: I feel perfectly that there is no other group of men busy, at any occupation in this country, whose very business calls them to deal so in accuracies and to speak in niceties. This in the end cannot help but beget the faculty of telling the truth. And this is needed, for how few there are who have the saving grace of veracity! But you have it. And it is a saving grace; for the comment is as apt to-day as when Falstaff first made it: "Lord, how this world is given to lying!"

Modesty: Your modesty is due to the fact, not that you know so little, but that, knowing so much, you know best that there is so much more to learn. Like Sir Isaac Newton, the more you know the more you feel yourselves like children picking up pebbles on the shore of the infinite sea of knowledge, yet unknown.

Courage: Your fourth characteristic is courage, but it is of a special kind—the courage of the mind. There was a time when men built their knowledge upon their opinions and made to be a test of truth the question whether they wanted to believe so and so. You have taught them to reverse all that entirely. Your method is the opposite of my friend's, who said to me one day, he being a newspaper reporter: "Tell me what you want to prove and I will send you the statistics." You begin by saying: "What are the statistics? Let me have them first, and I will stand by what they prove." And it is safe to do this; for the universe of God is fireproof: if you are in the search of truth any time and cannot find it for the dark, it is safe anywhere to strike a match.

Being thus industrious in your work, accurate in your thinking, modest in your attitude toward knowledge and frank and fearless in facing facts in the search for truth, you are needed in this country in this generation. You are needed in politics; you are needed in religion, you are needed in society; you are needed in the realm of finance; you are needed in the realm of finance; you are needed in the field of morals. To quote a passage from the ancient story from the book of Esther, "Who can tell?" saith the Scripture, "Who can tell but that thou art come into the kingdom for just such time as this?"

THESES FOR DEGREE OF B.A.Sc.

The following is a complete list of theses presented by men of the fourth year for the degree of Bachelor of Applied Science. The bracketed figures following each name designates the course the candidate is following, thus: (1) Civil Engineering; (2) Mining Engineering; (3) Mechanical Engineering; (4) Architecture; (5) Analytical and Applied Chemistry; (6) Chemical Engineering; (7) Electrical Engineering; (8) Metallurgical Engineering.

Candidate.	Title of Thesis.
Adlard, L. S. (1)	Water Purification.
Anderson, A. C. (1)	Concrete Arch Dams.
Arksey, G.A. (1)	Breakwaters Built in Open Water.
Arthur, R. M. (2)	Roasting and Sulphuric Acid Leaching of Eustis Copper Ore.
Austin, F. D. (1)	Chemical Purification of Water Supplies.
Ball, W. V. (7)	Comparison of Steam and Electrical Locomotives.
Banbury, T. R. (7)	Step-up Transformer Stations.
Beacock, V. A. (7)	Speed Control of Alternating Current Motors.
Bennett, P. (1)	Concrete Roads.
Birrell, A. L. (7)	High Tension Power Protection Appliances.

Black, H. M. (7)	Application of D. C. Motors to Rolling Mill Drive.
Blackwell, R. H. H. (1)	Pile Foundations.
Bonus, W. H. (7)	The Electrification of a Railway Terminus.
Breithaupt, J. E. (6)	The Manufacture of Leather.
Brouse, E. D. G. (1)	Investigation of a Watershed for Power Purposes.
Brown, L. R. (1)	Reinforced Concrete as Applied to Sewers and Sewage Disposal.
Buchanan, F. M. (1)	The Use of Bitumen as a Paving Material.
Budd, H. C. (7)	Electrification of Steam Railroads.
Burden, H. J. (4)	An Up-town Hotel in a Large City.
Burness, K. C. (4)	Civic Planning in Canada.
Carmichael, F. N. D. (1)	Dipper Dredging.
Catto, R. W. (4)	A Gentlemen's Country Club.
Chandler, F. H. (7)	Protection of High Tension Circuits Against Static Stresses.
Christner, J. C. (1)	Concrete Piling.
Cockburn, R. M. (1)	Measurement and Computation of Flow in Streams.
Code, W. W. (7)	Single Phase Railway System.
Cook, J. D. (1)	Concrete Abutments.
Crealock, A. B. (1)	Commercial Dock Design.
Da Costa, W. R. (1)	Water Purification.
Daniel, N. H. (1)	Grade Separation.
Davey, C. G. (3)	The Four-Cycle Gasoline Motor.
Davidson, G. P. (7)	Synchronous Converters.
Davidson, J. J. (4)	Canadian Government Building in London, Eng.
Dean, W. A. (7)	Mercury Arc Rectifiers.
Deverall, E. V. (1)	Methods of Reducing the Fire Hazard in Buildings.
Dibblee, J. (7)	Automatic Voltage Regulation.
Dickson, W. L. (1)	Concrete as Applied to Road Building.
Downey, G. A. (1)	A Scheme for Provincial Highway Development with Special Reference to Ontario.
Edwards, G. R. (4)	A Gothic Church.
Elliot, R. V. (7)	Electric Furnace Electrodes.
Emmerson E,.R. (2)	The Hydrometallurgy of Stibnite Ores.
Evans, A. C. (1)	Plane Table and Stadia Topography. (Methods of U. S. and Canadian Geological Surveys.)
Falconer, H. S. (1)	Hydrographic Surveying—Soundings.
Flannery, D. T. (7)	Oil Circuit Breakers.
Ford, J. W. H. (1)	Reinforced Concrete Arch Bridges.
Fraser, W. R. (1)	Retaining Walls.

French, W. G. (1) ....Dry-dock Construction in Canada.
Frid, H. P. (4) ....Efficiency in Building Construction.
Fulton, W. J. (1) ....Retaining Walls.
Galbraith, R. D. (1)......Pneumatic Caisson Practice.
Geale, C. N. (1) ....Purification of Public Water Supplies.
Glass, L. G. (6) ....Oxidation of Ammonium Sulphite to Ammonium Sulphate.
Gooderham, G. A. (1) ....The Value of Concrete Construction as Applied to Fire-resisting Structures.
Gould, W. H. R. (7) ......Developments in Hydraulic Turbines.
Graham, T. S. (4) ....Office Building—Eight to Ten Stories.
Grange, E. R. (1) ....Reinforced Concrete Floors.
Gray, E. D. (1) ....Silica as an Effective Road Binder.
Gray, G. D. (7) ....Drainage of Agricultural Lands.
Gray, J. (3) ....Steam Boilers.
Griffiths, G. E. (7) ....Power Factor Correction and Voltage Regulation by Synchronous Machines.
Haas, M. S. (2) ....Cupellation Losses in Silver Assaying.
Halford, D. S. (2) ....A Flotation Treatment of Gold Ores from Porcupine.
Hall, W. T. (2) ....The Cyanide Treatment of Porcupine Gold Ores.
Hanlon, J. E. (2) ....Some Phases of "Pyritic Smelting."
Hayward, C. (1) ....Sewage Disposal for Suburban Districts.
Higgins, L. T. (2) ....A Study of Certain Aluminium-zinc Alloys.
Hogarth, C. E. (1) ....Caisson Construction for Foundations.
Ireland, T. P. (7) ....Electric Locomotives.
Ironside, A. G. (7) ....The Single Phase Railway System.
Jackson, C. W. H. (1)....Treatment and Utilization of Woollen Mill Waste.
Jefferson, K. A. (7) ......Development of Power Plants from Storage Reservoirs.
Johnston, G. W. F. (1)...Grade Separation.
Jones, C. M. (7) ....Induction Motors—Their Design and Commercial Applications.
Jones, R. D. (2) ....The Function of Time and the Influence of Grain Sizing on the Vitrification of Clay.
Jupp, E. H. (1) ....Water Purification for Public Use.
Keys, C. R. (7) ....Lightning and Static Arresters.
Kohl, H. (5) ....The Manufacture and Uses of Sodium Sulphite.
Laidlaw, R. E. (1) ....Sewage Sludge Disposal and Utilization.
Lamb, G. J. (1) ....Gauging of Large Rivers.
Lawrence, G. W. 7) ......Protection Relays.
Leach, H. O. (1) ....The Sanitary Disposal of Refuse.
Lloyd, R. H. (3).........Steam Turbines.

Lockhart, W. E. (1)	Railway Ballasting.
Longworthy, W. E. (1)	The Reinforced Concrete Arch.
Lount, C. T. (1)	Drainage Problems in Saskatchewan.
Lye, R. G. (1)	Pile Foundations.
Macdonald, C.A. (1)	Municipal Water Supplies.
Macdonell, I. M. (2)	An Examination of Certain Zinc-Aluminium Alloys.
Macpherson, H. E. (1)	Reinforced Concrete Floors.
McCaffrey, W. R. (1)	Purification of Water by Ozone.
McCort, C. R. (1)	Breakwaters.
McDonald, K. D. (1)	Photographic Surveying.
McDonald, J. P. (1)	Cofferdams.
McGie, W. R. (3)	Balancing of Petrol Engines as Applied to Motor Vehicle Types.
McGugan, D. F. (1)	Irrigation.
McIntyre, J. S. (7)	Single Phase Alternating Current Distribution from Station to Consumer.
McKague, E.V. (1)	Docks, Breakwaters and Retainage Pertaining to Harbor Development.
Martin, E. T. (7)	Synchronous Motors.
Meitz, W. H. (1)	Tunnelling (Railways).
Mills, F. L. (2)	Some Phases of Pyritic Smelting.
Mitchell, G. (1)	Earthen Dams and Embankments for Reservoirs.
Mogan, J. T. (1)	Subaqueous Construction.
Monteith, E. M. (7)	Electric Mine Hoists.
Morris, A. (4)	Group of Modern Farm Buildings.
Morris, B. M. (1)	Cast-and-Driven Concrete Piles.
Morris, W. D. (5)	Chemistry of Foods.
Muir, J. M. (2)	The Function of Time and the Influence of Grain Sizing on the Vitrification of Clays.
Neilson, M. A. (1)	Concrete Highway Bridges.
Nicklin, H. S. (1)	Percolating Filters.
O'Connor, E. B. (1)	Concrete Roadways.
Omand, W. M. (1)	Subaqueous Foundations for Bridges.
Paul, R. A. (1)	The Economic Value of Fireproof Building Construction.
Payne, A. N. (3)	Mechanical Refrigeration: The Ammonia Compression System and Its Application to the Manufacture of Artificial Ice.
Pearce, L. P. (1)	The Scientific Treatment of Sewage by Sprinkling Filters.
Peck, H. M. (1)	Topographic Surveying.
Peterkin, S. M. (1)	Highway Construction and Maintenance.
Porter, C. F. (1)	Concrete Road.
Porter, J. E. (1)	Typical Breakwaters, referring particularly to Freshwater Types.

Powell, W.D. (2)	Comparison of Agitation, Frothing and Bubble Box Methods.
Purdy, W. F. P. (7)	Interurban Railways.
Raley, W. E. (1)	Concrete Building Foundations on Earth.
Rance, C. C. (1)	Rural Highways.
Rankin, G. (1)	Failures in Reinforced Concrete Building Construction.
Redman, W. B. (1)	Reinforced Concrete Docks.
Reid, F. G. (3)	Engineering Details Concerning the Installation and Operation of "Taylor System."
Relyea, P. J. (6)	The Manufacture of Barium Salts.
Richardson, A. A. (1)	Earthen Dams.
Robertson, A. S. (3)	Subaqueous Concrete Construction.
Rose, J. T. (1)	Public Water Supply—Purification of Water by Sedimentation and Filtration.
Ross, A. C. (7)	Outdoor Transformer and Switching Stations.
Ross, J. (2)	Roasting and Leaching of Eustis Copper Ore, with Sulphuric Acid.
Rowe, H. M. (1)	The New Welland Ship Canal and the Proposed Georgian Bay Canal—A Discussion of the Respective Merits and Engineering Difficulties of the Two Routes.
Russell, W. E. (7)	Voltage Regulation.
Rutter, G. W. (4)	A War Memorial.
Ryan, W.. (7)	The Relative Cost of Electrical Power as Generated by Steam and Water Power Plants.
Savage, E. W. (7)	Protection from Lightning.
Scott, A. G. (7)	The Storage Battery as a Factor in Central Station Control.
Scott, E. H. (1)	Construction of Railway Culverts.
Scott, R. G. (1)	Topographical Surveying.
Seymour, N. F. (7)	Circuit Opening Devices for the Protection of Electric Circuits and Machinery.
Shaw, J. H. (1)	Irrigation.
Sheehy, J. S. (1)	Concrete Dam Construction.
Shier, W. G. (3)	The Steam Turbine and Its Accessories.
Simpson, C. N. (1)	Water Purification.
Sinclair, R. B. (1)	Tunnelling.
Smyth, A. H. (3)	The Application of Engineering to the Management of a Woodworking Plant.
Steel, W. A. (7)	Polyphase Metering.

Stitt, J. B. (2)...........An Assay Method for the Gold Silver Tellurium Ores of Kirkland Lake.
Stone, J. D. (3)..Recent Improvements in Locomotives.
Storey, G. C. (7).........Power Measurement in Three-Phase Circuits.
Stroud, J. E. C. (2)......The Electro-Analysis of Zinc.
Suhler, A. N. (7)........Motor Control.
Taylor, A. N. (7)........High Power Lamps.
Thompson, H. B. (1).....The Structural Design of Office Buildings.
Tillson, G. D. (3)........The Cupola Furnace.
Tillson, L. B. (1)........Measurement of River Discharge.
Tom, J. A. (1)...........Modern Methods of Water Purification, with Special Notes on the Ultra Violet Ray.
Uffelmann, W. (5).......The Manufacture of Gasoline.
Vezina, A. L. (7)........The Construction and Maintenance of Macadam Roads.
Ward, A. L. (7).........Commutation.
Weir, F. E. (1)..........The Use of Concrete in Piling.
West, C. W. (1).........The Canalization of Rivers (with special reference to the Trent Canal).
Williams, J. N. (1)......Timber Piling.
Wilson, J. C. (1)........Metallic Roofing.
Wood, H. A. (1).........Docks, Breakwaters and Retention Work, as Applied to Harbor Development.
Wyman, H. K. (7).......Automatic Protection of High-Voltage Systems.

T. A. McElhanney, B.A.Sc., '10, is a member of McElhanney Bros., civil engineers and land surveyors, Dominion Trust Building, Vancouver, B.C.

N. D. Seaton, B.A.Sc., '11, is at Timmins, Ont., with the Northern Canada Power Company.

M. R. Shaw, B.A.Sc., '09, is assistant secretary and chief chemist for the Export Oil Corporation at Waggaman, La.

J. M. McGregor, '08, is a member of the firm, McCubbin & McGregor, surveyors and engineers, Chatham, Ont.

W. K. Thompson, B.A.Sc., '13, is technical clerk in the Land Patents Branch, Department of Interior, Ottawa.

G. A. Warrington, B.A.Sc., '10, is employed in the Department of Public Works of Manitoba, Winnipeg, Man.

T. G. Gravely, B.A.Sc., '11, is at present on the editorial staff of "The Globe," Toronto.

E. C. R. Stoneman, B.A.Sc., '14, is assistant power engineer, Bell Telephone Company of Canada, Montreal, P.Q.

APPLIED SCIENCE

INCORPORATED WITH

Transactions of the University of Toronto Engineering Society

DEVOTED TO THE INTERESTS OF ENGINEERING, ARCHITECTURE
AND APPLIED CHEMISTRY AT THE UNIVERSITY OF TORONTO

Published every month in the year by the University of Toronto Engineering Society

MANAGING BOARD

J. E. Ritchie, B.A.Sc.	Editor-in-Chief
H. A. Babcock, '16	Civil Sec.
T. A. Daniel, '16	Elec. and Mech. Sec.
B. A. McCrodan, '16	Mining Sec.
J. L. Skinner, '16	Arch. Sec.
D. Boyd, '16	Chem. Sec.
C. E. Hastings, '16	Ex-Officio U.T.E.S.
W. B. Honeywell, '17	Ex-Officio U.T.E.S.

Associate Editors

H. E. T. Haultain, C.E.	Mining
H. W. Price, B.A.Sc.	Mech. and Elec.
C. R. Young, C.E.	Civil
J. W. Bain, B.A,Sc.	Chemistry

Treasurer: Geo. H. Sohn, '17

Subscription Rates

Per year, in advance	$2.00
Single copies	.20

Advertising rates on application.

Address all communications;

Applied Science,
Engineering Bldg., University of Toronto,
Toronto, Ont.

EDITORIAL

We beg to call the attention of our readers to the fact that after May 1st, 1915, the duties of Editor of "Applied Science" and Secretary of the Engineering Society will be assumed by Russel G. Lye, '15. We believe that the graduates will give Mr. Lye unstinted support in carrying on the work of the Society, as it is very desirable that each one should do his share, especially at the present time. It is a difficult task to keep correct records of all the "School" men, in view of the fact that the nature of their work necessitates frequent changes of addresses. We would ask every man to keep the Secretary well informed of his address and occupation, and also send in any items of news which would be of interest to his fellow alumni.

Furthermore, we know that some of our graduates who are among the most loyal of "School" men, do not realize the present necessity of concrete as well as moral support. The number of our graduates has increased to such an extent that the Engineering Society finds the publication of "Applied Science" to be a heavy burden. We do not believe that any graduate wishes the entire load to fall upon the student members of the Society. This contention is borne out by the fact that most of the graduate member have readily assumed their share of the responsibility, but we aim to have every "School" man an active participant in the work of the "School" men.

A few months ago a personal letter was sent to each of our readers, with a view to soliciting their co-operation. The response has been very encouraging, and we trust that the remaining few will do their share to maintain the esprit de corps of the "School" by helping to keep "Applied Science" among all the graduates, and so strengthen the bond which unites "School" men.

The following 'School" men have enlisted with the Canadian Overseas Railway Construction Corps for service in France and Belgium: J. A. Tilston, '14, W. G. French, '15, R. R. Hewson, '15. We understand that this corps has gone to West St. John for a month or more of training.

The following "School" men have enlisted with the Second Canadian Contingent, in addition to those previously mentioned in "Applied Science": N. A. Burwash, '03, with the Engineers; B. H. Segre, with 4th Bde., 13th Bn.; R. L. Junkin, '13, with the Engineers; C. R. Avery, '13, with 4th Bde., 13th Bn.; T. F. Howlett, '13, with the Engineers; N. F. Parkinson, with 4th Bde., 13th Bn.; H. Webster, '13, with 4th Bde., 13th Bn.; H. J. Burden, '15, with Mississauga Horse; W. E. Raley, '15, with the Engineers; W. D. Powell, '15, with the Engineers; T. A. Daniel, '16; J. S. Wilson, '16; T. E. Armstrong, '16; H. S. Gooderham, '18, with 20th Bn.; H. Stewart, '16, with Machine Gun Section, 20th Bn.; W. H. R. Gould, with Second Divisional Cycle Corps; W. F. Hadley, '15, with the Corps of Guides; T. L. Harling, '18, with the Mounted Rifles; T. B. Jack, '18; A. P. Maclean, '17; J. S. M. Wallace, '17, with 25th Battery, C.F.A.

The following men have enlisted with the Third Contingent: F. R. Allan, '18, with the Machine Gun Detachment, 35th Bn.; A. M. Thomas, '16, with Company No. 2, 35th Bn.; C. H. Wheelock, with Machine Gun Detachment, 35th Bn.; A. G. Scott, '15, with 42nd Regiment, Petawawa, Ont.

Lieut. M. S. Haas, '15, is on duty, Toronto Civic Guard, Island Post.

R. D. Galbraith, '15, and Lieut. E. V. McKague, '15, are taking a course at the Royal School of Cavalry, Stanley Barracks, Toronto.

S. A. Lang, B.A.Sc., '14, who went to Chile a year ago with the Braden Copper Company at Rancagua, has recently been promoted to head of the sampling department.

J. A. D. McCurdy, '07, will be in charge of a new aviation school at the Long Branch Rifle Ranges. Mr. McCurdy's flying school, which has recently been established by the Department of Naval Service, will be a training school for recruits for the Royal Naval Air Service. Mr. McCurdy is one of the best known aviators on this continent. His flight from Key West to Cuba about four years ago created much interest, and he has the distinction of being the first aviator to dispatch a wireless message from an aeroplane. A number of "School" men have already sent in their applications to join this corps.

TROPHY FOR PUBLIC SPEAKING

Presented to the Engineering Society by a number of graduates.

R. W. Soper, B.A.Sc., '13, has a private practice as architect at 168 Front St., Sarnia, Ont.

J. A. Coombs, '13, is employed on the construction of the Federal Railway of the United States, in Alaska.

B. W. Waugh, B.A.Sc., '08, recently returned to Ottawa, after completing a base line survey at Port Nelson, Hudson Bay, for the Dominion Department of Interior.

E. R. Gray, B.A.Sc., '13, formerly Division Engineer, Sewer Department, City Hall, Toronto, has recently received an appointment as assistant city engineer of Hamilton, Ontario.

F. T. McPherson, '15, was elected president of a recently established engineering society in Saskatoon, Sask.

C. S. Cameron, '11, has a practice as Dominion and Saskatchewan Land Surveyor, at the Merchants Bank Building, Scarth St., Regina.

MARRIAGES.

Cory—Telfer.

On April 10th, 1915, the marriage was solemnized at St. Thomas' Church, London, England, of R. Y. Cory, B.A.Sc., '08, Captain, 15th Battalion (48th Highlanders), 3rd Brigade, First Canadian Contingent, British Expeditionary Force, of 5 Deer Park Crescent, Toronto, to Miss Beatrice Edna Telfer, of Collingwood, Ont.

Nourse—Webster.

On April 10th, 1915, Mr. A. E. Nourse, B.A.Sc., '07, of Toronto, was united in marriage to Miss Kate Augusta De Neville Webster, of Toronto.

Curzon—Banks.

On Wednesday, April 14th, 1915, Mr. J. H. Curzon, '11, of the staff of the Main Drainage Department, City Hall, Toronto, was married to Miss Alva Banks, daughter of Mr. and Mrs. John L. Banks, 178 Kingston, Road, Toronto. Mr. and Mrs. Curzon left on a trip to New York and other points in the United States.

DIRECTORY OF THE ALUMNI.

Corbould, C. E. B., '14, is in the Engineering Department, Hydrographic Survey Branch, Department of Interior, Nelson, B.C.

Cory, R. Y., '08, is captain with 15th Battalion, 3rd Brigade, First Canadian Contingent, France.

Coulter, G. P., '07. We do not know his address.

Coulson, C. L., '03. His home is in Welland, Ont. We do not know the nature of his professional work.

Cousins, E. L., '06, Harbor Engineer for the city of Toronto, has been allowed eight or nine months of leave of absence to undertake the preparation of plans for a system of radials and radial entrances for the city.

Coultard, R. W., '99, is associate editor, "Mine, Quarry and Derrick," Calgary, Alta.

Coumans, O. F., '11, is Provincial Drainage Engineer, Regina, for the Saskatchewan Government.

Courtice, E. D. W., '14, is with the Waterworks Department, city of Toronto.

Cowan, W. A., '04, of Truro, N.S., is resident engineer for the Intercolonial Railway.

Cowper, G. C., '07. His home is in Welland, Ont. He is engaged on D.L.S. Topographical Surveys.

Craig, J. A., '99, is engaged in civil engineering and surveying at Prince Albert, Sask.

Coyne, H., '08, is chief draughtsman for Thomas & Thomas, Racine, Wis.

Craig, J. H., '10, is a member of the architectural firm of Craig & Madill, Manning Chambers, Toronto.

Craig, S. E., '04, is with the Canada Foundry Co., Toronto. His address is 72 Nina Ave., Toronto.

Crashley, J. W., '14, has 76 DeLisle Ave., Toronto as his address.

Crawford, A. W., '14, is with the 2nd Field Company, Canadian Engineers, Second Contingent.

Creighton, A. G., '06, is a member of the firm of Creighton & Strothers, architects and structural engineers, Prince Albert, Sask.

Crerar, S. R., '04, is lecturer in surveying, Faculty of Applied Science and Engineering, University of Toronto.

Crosby, N. L. R., '05, is contracting engineer with Toronto Structural Steel Co., Toronto, Ont.

Crosby, T. H., '09, is sales engineer with the Canadian Westinghouse Co., in the Vancouver office.

Crouch, M. E., '11, has a land-surveying practice at Port Arthur, Ont.

Cruthers, W. M., '11, is in the engineering department of the Canadian General Electric Co., at the Peterborough plant.

Culbert, J. V., '07, is with the Buffalo Mines, Cobalt, Ont.

Cumming, J. D., '08, is at Copper Cliff, Ont., with the Canadian Copper Co.

Cumming, R., '02, is a member of the contracting firm of Miller, Cumming & Robertson, Toronto.

Cunerty, T. J., '11, is with the Westinghouse Electric and Manufacturing Co., New York, in the export department.

Cunningham, C. H., '11, is designing engineer for Thor Iron Works, Toronto, of which firm he is a director.

Cunningham, R. H., '09, is at Windsor, Ont. He is sales engineer for the Hoskin Manufacturing Co., Detroit.

Currie, W. M., '04, is a member of the staff of the Canada Steel Co., Hamilton.

Curtis, W. T., '13, is with the Hollinger Mines, Timmins, Ont.

Curzon, J. H., '11, is employed in the sewer department, City Hall, Toronto.

Cuthbertson, W., '14, is employed with the Department of Public Works of Ontario, on the construction of the Toronto-Hamilton road.

Dahl, A. D., '08, has Midland, Mich., for his address. He is research chemist for the Dow Chemical Co.

Dallyn, F. A., '09, is with the Ontario Board of Health as consulting expert, in charge of the experimental station at Toronto.

Dalton, G. F., '14, is with the Geodetic Survey of Canada, Department of Interior, Ottawa.

D'Alton, F. K., '11, is on the staff of Ridley College, St. Catharines, Ont.

Daniels, W. N., '06, is at Noble Road, Jenkintown, Pa., as Superintendent of Reinforced Concrete Construction, for the Guarantee Construction Co. of New York City.

Danks, F. A., '08, is with the Waterworks, Department, City of Toronto. He is at the engineer's office, filtration plant, Centre Island, Toronto.

Danks, C. N., '09, is with the Jenckes Machine Co., Sherbrooke, Que., as engineer.

Dann, E. M., '09, is District Engineer, British Columbia Hydrographic Survey, Dominion Water Power Branch, Department of Interior Kamloops, B.C.

Darling, E. H., '98, is a member of the firm, McPhie, Kelly & Darling, consulting engineers, Bank of Hamilton Building, Hamilton, Ont.

Darroch, J., '08, has no address with us at present. When last heard from him he was with the Autoparts Mfg. Co., Detroit, Mich., as draughtsman.

Dashwood, R., '14, is on active service with the British Army.

Dates, A. J., '13, is with the State Railway Commission of Michigan. He lives at 35 Farrand Ave., Highland Park, Mich.

Davidson, H. D., '13, is employed on the construction of the Welland Ship Canal, St. Catharines, Ont.

Davidson, R. D., '14, is engaged in land survey work with A. H. Hawkins, D.L.S., Le Pas, Man.

Davis, A. I., '09, is at Fort Dodge, Ia.

Davis, J., '09, is sales engineer for the Canada Foundry Co., in connection with the Ottawa office.

Davis, H. W., '09, resides in Kingston, Ont., where he is in charge of the power department of the Davis Tanneries, Ltd.

Davis, H. C., '09. We do not know his present address.

Davis, R. S., '07, is manager of the Calgary office of the Canadian Westinghouse Co.

Davis, W. B., '11, is engaged on the construction of the Trent Valley Canal, Frankfort, Ont.

Davison, J. E., '00, is in the engineering department of the Canadian Northern Ry. Co., at Winnipeg, Man.

Davison, A. E., '03, is with the Hydro-Electric Power Commission, as engineer, with Toronto as headquarters.

Dawson, I. H., '09, is assistant resident engineer, section 5, Welland Ship Canal, Allanburg, Ont.

Deacon, T. R., '91, is president and general manager of the Manitoba Bridge and Iron Works.

Dean, C. D., '10, has Alexandra Apartments, Sarnia, Ont., for his home address. We do not know his business address.

Death, N. P. F., '06, is a member of the firm of Death & Watson, electrical engineers and contractors, Toronto.

DeCew, J. A., '96, is in Montreal, Que., where he has a consulting practice in chemical engineering.

DeGuerre, F. C., '11. We do not know his address.

Deitch, E. L., '13, is inspector with the Ontario Hydro-Electric Power Commission.

Delahaye, W. H., '09, is in the Patent Office, Dept. of Agriculture, Ottawa.

Delamere, R. D., '14, is a member of Clipsham & Delamere, manufacturers of motor cars, 1896 Dundas St., Toronto.

De Laporte, A. V., '10, is chemist with the Provincial Board of Health, Toronto.

Depew, H. H., '04, is in Edmonton, Alta., at 649 First Street. We do not know the nature of his employment.

Derham, W. P., '09. He has no business address on our fyles.

Diamond, R. W., '13, is with the Anaconda Copper Mining Co., Anaconda, Montana.

Dickson, G. W., '00, is with the Laurentide Co., Limited, Grand Mere, Que., paper manufacturers, as superintendent of the ground wood pulp mill and the log preparing mill.

Dickenson, E. D., '00, is with the General Electric Co., at Schenectady, N.Y.

Dill, C. W., '91, is managing director of the National Paving and Contracting Co., Winnipeg, Man.

Dixon, H. A., '00, is at Jasper, Alta., as district engineer for Mackenzie, Mann & Co., on the C. N. R.

Dobbin, R. L., '10, is superintendent of the waterworks department for the city of Peterborough, Ont.

Dobson, W. P., '10, is in charge of the testing department of the Ontario Hydro-Electric Power Commission, at their plant on Strachan Ave., Toronto.

Dobie, J. S., '95, resides at Thessalon, Ont. He is engaged in O.L.S. and D.L.S. work.

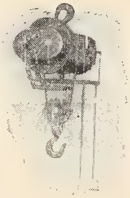
Dodds, W. A., '09, is chemical engineer for the Penman Littlehales Chemical Co., of Syracuse, N.Y.

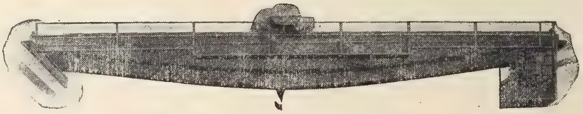
Douglas, F. W., '14, of 276 Palmerston Ave., Toronto, has been employed with Geo. B. Meadows Co., Ltd, manufacturers of wire, iron and brass materials, Toronto.

Douglas, R. H., '08, is with the Department of Public Works, Edmonton, Alta.

INDEX TO ADVERTISERS

Art Metropole, Limited .... Outside Back Cover
Babcock & Wilcox, Limited ii
Brotherton, J. vii
Canadian Engineer, The i
Canadian-Chicago Bridge and Iron Works iii
Canadian Kodak Co., Limited ix
Crown Blue Print Co., The v
Dietzgen, Eugene, Co., Limited i
Dominion Bridge Co., Limited .... Inside Front Cover
Empire Typewriter viii
Farmer Bros. .... —
Francis, W. J. .... Inside Back Cover
Goldie & McCulloch Co., Limited .... Inside Front Cover
Hamilton Gear & Machine Co. vii
Harkness & Oxley .... Inside Back Cover
Higgins, Charles M. iii
James, Loudon, Hertzberg .... Inside Back Cover
Lufkin Rule Co., Limited .... Inside Back Cover
McBride, Percy A. viii
Mitchell, C. H. & P. H. .... Inside Back Cover
Morris Crane and Hoist Co., The Herbert ii
Northern Crane Works .... —
Rail Joint Co., of Canada, Limited iii
Stock & Bickle viii
Supply Department .... Inside Back Cover
Thorold, F. W. .... Inside Back Cover
Trussed Concrete Steel Co., of Canada, Limited iii
University of Toronto x
Wettlaufer iv





CRANES
ELECTRIC HOISTS. AIR HOISTS
NORTHERN CRANE WORKS LIMITED
WALKERVILLE, ONTARIO
TORONTO OFFICE: TRADERS BANK BLDG.
Made in Canada

THE CROWN BLUE PRINT CO.
Blue, White and Black Prints, Etc.
Best of Service Out-of-town work finished and mailed the day received. Special prices on oul-of-town work.
37 Adelaide St. West, Toronto Tel. M. 1419 Residence H. 1948